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# Biodiversity on the brink: evaluating a transdisciplinary research collaboration

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## Abstract

Global biodiversity is facing an extinction crisis. Australia has one of the highest terrestrial species extinction rates in the world. Scientists, policy advisors and governments have recommended that the issue be addressed at a landscape-scale, while noting that there are significant knowledge gaps that are hampering implementation of such an approach. From 2011-2015, the Australian Government funded a transdisciplinary research program, the Landscapes and Policy Hub, to meet this need. Transdisciplinary research is widely acknowledged as essential to address the complexity of contemporary environmental problems. Given that such research programs are in their infancy, it is important to evaluate their efficacy and provide an empirical basis for improving their design. This

paper presents an evaluation of the strategies fostering transdisciplinarity adopted by the Landscapes and Policy Hub. A heavy emphasis on communication, with skilled knowledge brokering, regular face-to-face meetings using participatory activities and shared field engagements enhanced transdisciplinary interaction between researchers and research users. However, establishing a fully integrated interdisciplinary research program remained a challenge. Efforts to enable shared conceptual frameworks to emerge through adaptive application of theory in practice could have been balanced with increased effort at the outset for researchers and research users to collaboratively formulate shared research questions, leading to the establishment of teams that could address these questions through cross-mobilisation of interdisciplinary expertise.

*Keywords: transdisciplinarity; integrative research; problem-oriented interdisciplinary research; knowledge brokering; research project evaluation; landscape-scale conservation management*

## Introduction

Researchers and natural resource managers have long known that environmental problems, including biodiversity decline, are wicked in character given they involve a mixture of fact and values, there are no right answers, and science and engineering are unlikely to offer easy solutions (Rittel & Weber, 1973). The level of biodiversity loss is arguably our planet's first single species driven mass extinction event (Williams et al., 2015). Its deterioration has gone beyond levels considered safe for global societal development, even though the impact of this loss on the functional diversity of the biosphere and its consequences for humanity is yet to be fully understood (Steffen et al., 2015). Understanding and investigating the consequences of biodiversity loss and remedial measures requires an appreciation of the complex and co-evolving interactions between social and ecological systems (Dietz, Ostrom, & Stern, 2003; Liu et al., 2007; Torkar & McGregor, 2012). This requires collaboration across multiple disciplines<sup>1</sup>, as well as practical experiential knowledge of those who use, manage and care for the environment (Weber, Belsky, Lach, & Cheng, 2014). The challenge is how to establish research projects able to integrate diverse sources of knowledge and experience, and be sufficiently adaptable (van Kerkhoff, 2014; Campbell et al., 2015).

A preference for large collaborative research projects transcending disciplinary boundaries and engaging with research users is also evident in the way governments fund research on environmental management issues. In Australia for example, Cooperative Research Centres have been established to engage research users in the multidisciplinary production of knowledge and tools to improve water use efficiency ([www.irrigationfutures.org.au](http://www.irrigationfutures.org.au)), agricultural sustainability

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<sup>1</sup> By disciplines, we refer to the departmentalisation of academic structures into recognised areas of specialisation (Max-Neef, 2005; Tress, Tress, & Fry 2005a).

([www.futurefarmonline.com.au](http://www.futurefarmonline.com.au)), and wildfire management ([www.bushfirecrc.com](http://www.bushfirecrc.com)). In Europe, public participation is a prescribed component of all research associated with the European Water Framework Directive, prompting a heavy emphasis on research activity that engages society for mutual learning (Pahl-Wostl, Mostert, & Tàbara, 2008). Engagement of social actors is also a key strategy adopted by research related to Europe's biodiversity conservation policy (Winkel et al., 2015).

A number of these efforts can be regarded as “transdisciplinary”, as research that traverses across and beyond scientific disciplines, and engages research users and other key stakeholders in its design and execution. Despite an emerging consensus that transdisciplinary research involves integration at the interface of scientific questions and societal problems (Jahn, Bergmann, & Kei, 2012), there are different emphases in how it is best distinguished from interdisciplinary research. In this paper we draw on Tress, Tress and Fry (2005c), Allen et al. (2014) and Lefroy, Grun, Jakeman and McKee (2012) to adopt the following distinctions:

- Multidisciplinary research – multiple disciplines, with loose cooperation largely around the exchange of knowledge.
- Interdisciplinary research – crossing disciplinary boundaries to develop integrated knowledge and theory, and solve problems.
- Transdisciplinary research – crossing disciplinary boundaries and unsettling the distinction between research providers and research users (such as land managers and other stakeholders) to develop integrated knowledge and theory, and solve problems for science and society.

Based on these definitions, “transdisciplinary research” encompasses “interdisciplinary research”, but goes beyond it by engaging research users and other key stakeholders from the outset in problem definition, research design and determining delivery of research outcomes. As such, transdisciplinarity combines emergent ‘action research’ epistemological shifts (Schön, 1995; Midgley, 2003; Kemmis & McTaggart, 2005) with research needing to transcend disciplinary boundaries to address issues that arise when engaging social actors with different ‘ways of knowing’ (Scholz & Steiner, 2015a). Involving actors beyond academia requires new collaborative approaches to producing knowledge and making decisions (Lang et al., 2012). Application of this precept to biodiversity issues has inspired the need for collaborative research that invokes a process of co-producing governance, where scientists and managers jointly articulate the context, knowledge, process, and vision through which futures are determined and created (Wyborn, 2015). To

effectively turn these principles into practice requires improved processes for the formative evaluation of projects where transdisciplinary research strategies have been adopted.

In this paper we start from the assertion that crossing disciplinary boundaries and engaging research users is a necessary approach in responding to wicked problems faced by science and society (Midgley, 2003; Max-Neef, 2005; Brown, 2010; Scholz & Steiner, 2015a). Our focus is on the strategies and challenges of implementing a transdisciplinary research program, and as such, we do not attempt a critical reflection on transdisciplinarity more generally, or the discourses around the role of scientists in progressing sustainability and conservation goals. The purpose of the paper is to evaluate the effectiveness of strategies used by the Landscapes and Policy Hub (2011-2015) to foster transdisciplinary research. These strategies were informed by elements derived from the literature, as further detailed below in the Methods section. Other evaluations of transdisciplinary research programs in the environmental sciences have relied on reflections of those involved to identify factors contributing to success (Tress, Tress, & Fry, 2005b; Roux, Stirzaker, Breen, Lefroy, & Creswell, 2010) and barriers to overcome (Tress, Tress, & Fry, 2007). Brouwers et al. (2013) used an extended email exchange between the authors to identify what had supported and impeded collaboration and integrative research in the large and multidisciplinary forest health research program in which they were involved. Allen et al. (2014) developed an assessment rubric for transdisciplinary collaboration to formatively evaluate and adjust their practice over the life of their pest management research program in New Zealand. The evaluation on which the current paper is based combined Allen et al.'s (2014) assessment rubric approach with an innovative interactive workshop method using TurningPoint software.

## Research Program Context

The Landscapes and Policy Hub (LaP Hub) was established to identify practical solutions to the question of how to implement a regional-scale landscape approach to biodiversity conservation. The stimulus was a recommendation of the Hawke (2009) review of Australia's national environmental law, the *Environment Protection and Biodiversity Conservation (EPBC) Act 1999 (Cwlth)*. One criticism of the EPBC Act addressed by the review was that, after 10 years of operation, the number of threatened and endangered species listed under the Act had increased to more than 1,750 with very few coming off that list. Australia also has one of the highest extinction rates globally (DEWHA, 2010), with major causes being introduced species and changed fire regimes (Woinarski, Burbridge, & Harrison, 2015) – issues that need to be addressed at landscape scales. As a remedy, the Hawke review recommended that biodiversity be considered and managed at the scale of landscapes and

whole regions as well as species and communities in order to understand and manage the underlying causes of decline.

The LaP Hub was one of five large research hubs funded in 2011 by the Australian Government under the National Environment Research Program ([www.environment.gov.au/science/nerp](http://www.environment.gov.au/science/nerp)). The LaP Hub had a budget of \$AUD15 million over four years between 2011 and 2015 (\$AUD6.78 million from the Australian Government and \$AUD8.22 partner in-kind). It was hosted by the University of Tasmania and involved researchers there and from four other Australian universities. The program adopted a regional-scale case study approach, with the Tasmanian Midlands and the Australian Alps selected as contrasting case studies. The Tasmanian Midlands is a predominantly privately owned valley managed by hundreds of landowners for agricultural production. The Australian Alps is a mountainous, publicly owned protected area managed under multiple jurisdictions. Both regions have highly valued biodiversity attributes threatened by landscape-level processes.

The project was established to place emphasis on communication and to be futures oriented. It rested on three themes: communication, social and economic futures, and ecological futures (see Figure 1). Research expertise within these themes was organised into a series of projects including communications and knowledge brokering (a team led by the LaP Hub Director, and supported by 20% of funds allocated to the hub); social and institutional futures (human geography, sociology and political science expertise); economic futures (resource economics expertise); bioregional futures (landscape ecology and spatial science); climate futures (climate science); and projects related to wildlife; vegetation and fire; and freshwater ecosystems. Researchers were predominantly academics and graduate students associated with the partner universities, with additional research contributions from government agency staff. A steering committee was comprised of three representatives from the Australian Government's environment department as funding agency and research user, three from other research user agencies, as key stakeholders across the two case study contexts, and three external researchers. The principal outputs from the LaP Hub are available at [www.lifeatlarge.edu.au](http://www.lifeatlarge.edu.au).

[Insert Figure 1 about here, with title: "Figure 1: Landscapes and Policy Hub Organisational Structure"]

## Methods

Methods used to evaluate the LaP Hub comprised three parts: a literature review to identify relevant barriers to interdisciplinary and transdisciplinary research; critical reflection by the authors to best direct literature review findings to the LaP Hub context; and two surveys to elicit responses related

to these barriers and LaP Hub performance predominantly from its researcher participants. The rationale for referring to both interdisciplinary and transdisciplinary research barriers is that there are distinctive factors impeding transdisciplinarity, while interdisciplinary barriers impede both.

The literature review identified a range of barriers to interdisciplinary and transdisciplinary research as well as recommendations on how to overcome them (Tress et al., 2005a, 2005b, 2005c, 2007; Loibl, 2006; Roux et al., 2010; Allen et al., 2014; Buizer et al., 2015; Campbell et al., 2015; Scholz & Steiner, 2015b). A matrix was created to align the barriers identified in the literature into themes, which were then assessed by the authors in terms of their relevance to the LaP Hub context. The six barriers identified as most significant and contextually relevant were: physical distance between researchers (Tress et al., 2007; Buizer et al., 2015; Scholz & Steiner, 2015b); the time it can take to negotiate research activities (Tress et al., 2007; Lang et al., 2012; Allen et al., 2014); differences in culture, language and rules of evidence between disciplines (Loibl, 2006; Tress et al., 2007; Lang et al., 2012; Buizer et al., 2015; Campbell et al., 2015; Scholz & Steiner, 2015b); and the criteria used to assess academic performance (Tress et al., 2007; Allen et al., 2014; Buizer et al., 2015; Scholz & Steiner, 2015b). Barriers specifically affecting transdisciplinary research were: differences in institutional cultures (Loibl, 2006; Scholz & Steiner, 2015b); and inflexibility in structure, funding and operations (Tress et al., 2005a; Loibl, 2006; Campbell et al., 2015).

The six barriers so identified are shown in Table 1, and matched with the activities and strategies the LaP Hub adopted. Explanatory detail on the specific LaP Hub activities assessed is provided in Table 2. The Communications Team was primarily responsible for the design and ongoing evaluation and improvement of these activities to facilitate interdisciplinarity and transdisciplinarity. To ensure the surveys used to evaluate the LaP Hub's transdisciplinary performance were clearly focused, and to reduce the number of survey items, the authors undertook a rapid appraisal of each activity and strategy in terms of which barriers that activity or strategy aimed to overcome. This means that Survey 1 items excluded assessing activities and strategies against barriers with which they had little relevance, and included only those activities and strategies as matched with the barriers to which they had most relevance (i.e. those with two or more ticks [✓] in Table 1).

[Insert Tables 1 and 2 about here]

Two surveys were undertaken to evaluate the LaP Hub's transdisciplinary performance. The first was undertaken at a workshop held as part of the last meeting of hub researchers and staff in December 2014. The TurningPoint program was used to provide real-time display of group responses to a series of multiple choice evaluation questions, with each question followed by a brief discussion to analyse responses. The second survey was an emailed questionnaire undertaken six months later to obtain

further critical reflections from the hub's research leaders and steering committee members on its transdisciplinary performance.

### ***Survey 1 of LaP Hub researchers and staff***

Survey 1 respondents included those present at the December 2014 meeting, and thus draws primarily on the perspectives of hub researchers and staff (see participant classification by self-identification in Table 3). All questions used a five-point scale. Regarding the specific activities employed, respondents were able to choose "ineffective"; "somewhat effective"; "effective"; "very effective" or "extremely effective" (Table 1, first block listing specific Hub activities). For the other activities and strategies, respondents were given statements with which they could "strongly disagree"; "disagree"; "neither agree or disagree"; "agree" or "strongly agree" to document whether a particular strategy had, from their perspective, been deployed (Table 1, second block listing other activities and strategies).

[Insert Table 3 about here]

Data analysis included:

1. Aggregating data for each question to identify key results.
2. Identifying questions that elicited either consensus or divergent responses, and then investigating data associated with divergent responses to identify explanatory trends (for example, by assessing whether divergent responses were associated with particular types of respondents).
3. Identifying additional themes from notes of the discussion arising as results were presented.

### ***Survey 2 of LaP Hub research leaders and steering committee members***

Survey 2 was a 1-page questionnaire distributed by email comprising short answer questions and one using a five-point scale. All but two of the 18 recipients completed this survey. The intent was to elicit individual reflections on:

1. Each respondent's understandings of the meanings of interdisciplinary and transdisciplinary research and how much value they placed on these approaches in their work.
2. LaP Hub interdisciplinary and transdisciplinary performance, and suggestions of strategies that could have been adopted to improve outcomes.

To determine the level of value respondents placed on interdisciplinary and transdisciplinary research, the following five-point scale was used: "does not add any value to my work/research"; "adds little value to my work/research"; "adds some value to my work/research"; "adds a lot of



value to my work/research”; and “adds crucial value to my work/research”. Written responses to the other questions were analysed to identify common themes and any exceptions.

## Results

### ***Defining transdisciplinarity: different interpretations***

As noted in the Introduction, researchers differ in how they distinguish transdisciplinary from interdisciplinary research. We identified a similar disparity in how Survey 2 respondents made this distinction, even though their responses affirmed our notion that “transdisciplinary” research was seen to encompass “interdisciplinary” research and go beyond it.

Respondents generally conceived interdisciplinarity in similar ways, as involving two or more disciplines “*working together*” or “*across*”, “*collaborating*”, involving “*exchanges*” and “*interaction*”, and in one case “*combining disciplines to tackle an existing real world problem*”. The two exceptional interpretations were offered by research users, who used the above conceptualisation of interdisciplinary research as a way to describe their concept of transdisciplinary research, and thus distinguished interdisciplinary research as being “*different disciplines looking at a common problem through their different disciplinary lenses*” – i.e. not necessarily working together – or that the “*coming together*” only happened towards the end rather than from the beginning as they argued would be the case for transdisciplinary research.

Three dominant themes emerged in the way respondents distinguished transdisciplinary from interdisciplinary research. One theme focused on novelty as a distinguishing feature. Definitions included: “*novel combinations of disciplines that reframes the world and its problems*”; and an approach to research that ends up being “*greater than the sum of its parts*”. A second theme focused on the nature of the problem and how it should be solved: i.e., a “*shared problem*”; a problem identified as a focus for collaboration from the outset; and one that requires researchers to work beyond the confines of their disciplines, potentially changing their perceptions of the problem. The third theme was as adopted by those who designed the evaluation. Only one other respondent joined this group – an external researcher on the steering committee – and this person distinguished transdisciplinary research as that “*involving all actors in the inquiry process, including research funders, end users and intermediaries, as well as the providers of research from one or more scientific disciplines.*” One respondent saw no distinction, noting that while “trans” carries the meaning “across”, thus suggesting that ideas and methods from one discipline are applied by another, this was not how the respondent saw the term being applied.

However defined, most respondents considered interdisciplinary and transdisciplinary research to be crucial to or adding a great amount of value to their research or work (i.e. 13 and 14 respondents respectively out of 16).

### ***Effectiveness of strategies used by the LaP Hub to foster transdisciplinarity***

Survey 1 asked LaP Hub staff and researchers to evaluate the effectiveness of a number of strategies the hub had adopted, and consider statements related to the hub's transdisciplinary performance. Presentation of these results (see Tables 4 and 5) is supplemented here by Survey 2 results.

The face-to-face meetings were identified as effective in helping to overcome (1) differences in disciplinary language and culture (72% for both Hobart-based and cross-project meetings – see Table 4, Q1); (2) physical separation (by 96% of respondents regarding Hobart-based meetings – Table 4, Q4); and (3) differences in culture between researcher and research user institutions (between 86% and 100% for face-to-face meetings involving research users – Table 4, Q5). All respondents considered the two forums with research users in the Australian Alps as effective, with almost half considering them extremely effective (Table 4, Q5).

[Insert Tables 4 and 5 about here]

A significant strength was the hub's commitment to communications and knowledge broking, and to employing communications staff with skills, experience and enthusiasm for transdisciplinary research. The team included the hub director, a communications manager, and three knowledge brokers – two to broker between hub researchers and research users in the two case studies; the third to broker between the researchers and the project funder/ research user. Most respondents agreed that mentoring and support provided by the communication and knowledge brokering team helped them undertake transdisciplinary research (84%), as did events with research users (88%) (Table 5, Q7 and Q13) – these included face-to-face researcher meetings (twice a year at the LaP Hub headquarters in Hobart), bus tours of the case study areas, and *ad hoc* cross-project meetings (>300 over the life of the hub). The design of these events by the communication team proved particularly useful in nurturing transdisciplinarity. Researchers regarded the *ad hoc* meetings and *ad hoc* exchanges associated with the formal meetings as just as valuable (if not more so) than the formal meetings themselves.

However, the survey also indicated that many (62%) considered that insufficient time was allocated to early joint problem definition activities with research users (Table 5, Q10). This result was also a strong theme emerging from Survey 2. In particular, the lack of and need for a shared conceptual framework was raised several times by Survey 2 respondents (both researchers and research users).

The ongoing challenge the hub experienced in being able to bring together a range of disparate research pursuits as part of a coherent conceptual framework contributed to many Survey 2 respondents concluding that the hub did not fully deliver on its transdisciplinary potential. For example, one research leader commented that *“a true transdisciplinary research problem was not fully identified or pursued”*, and a steering committee member concluded that collaboration only began to emerge towards the end of the project because of the LaP Hub Director’s determined efforts *“to encourage, cajole and create imperatives to draw all streams of the study together into the whole”*. Such a comment underlines the importance of leadership skills associated with building transdisciplinary teams – skills that are different to those conventionally valued when assessing research performance and leadership.

While many Survey 2 respondents were critical of the hub’s performance in identifying a shared research agenda from the outset, there was praise for the way in which the hub sought to instil flexibility and adaptability of the research agenda to respond to ongoing interaction with research users. In particular, almost all project leaders considered the availability of contingency funds for new research projects a very effective strategy to overcome the barrier of inflexibility in research funding and operations (90% – Table 4, Q6). Achieving a balance between the need for a shared agenda from the outset and the need for flexibility was highlighted by these Survey 2 comments from a steering committee member:

*“Part of the challenge is to allow researchers the flexibility to...find organic and evolving solutions to real problems...When you plan every aspect of the research over multiple years in a highly regimented and bureaucratic way, you suffocate the creativity from research...You revert back to working in silos because that’s the easiest way to plan and guarantee particular outcomes.”*

The contingency funds were often used to respond to research user requests for assistance in solving small, specifically defined transdisciplinary research problems. Many of these required cooperation across the hub’s disciplinary-based teams, contributing to an overall appreciation by most Survey 1 respondents (91%) concerning the contribution that each discipline could make to the overall research agenda (see Table 5, Q8). However, this appreciation did not translate into an equivalent finding concerning the level of trust and respect between disciplines. Most offered an ambivalent response (54% neither agreed or disagreed that high levels of trust and respect between disciplines was a characteristic of the hub), and the response of those who offered an opinion was almost evenly split (see Table 5, Q9). Discussion of this finding at the workshop revealed some concerns about the level of collaboration between social and biophysical researchers, and in

particular that the timing and effectiveness of integrating social science research with that of other disciplines was a challenge for the hub. Survey 1 results also revealed that the hub's efforts to build collaboration between the social and biophysical sciences through the conceptual modelling workshops ended up being ineffective, with only 18% finding their use an effective strategy to overcome differences in research methods and rules of evidence (see Table 4, Q2).

### ***Suggestions for improvement***

Suggestions for improvement came from Survey 2 results. Respondents were asked what strategies could have ideally been used to support interdisciplinary and transdisciplinary research, and what would the outcomes have been if these strategies had been successfully implemented. Most suggestions focused on early development and ongoing evaluation of a shared research agenda. For example, one research leader suggested the following steps:

1. A series of workshops to be conducted at the outset where researchers and research users collaboratively develop research questions and a shared conceptual framework within which these questions can be addressed.
2. A follow-up workshop where researchers identify one or more methods for synthesising data and findings across all disciplines engaged in the research endeavour, the results of which are then reviewed by research users.
3. Annual reviews involving both researchers and research users to confirm or adjust research questions, conceptual framing and methodological synthesis.

A related suggestion was to arrange activities earlier on to (1) build awareness among all researchers of the value each discipline can bring to transdisciplinary research and (2) gain an upfront commitment to engage across disciplines. Another suggestion from two research leaders was to establish project-based interdisciplinary research teams rather than discipline-focused teams. This suggestion underlines the transdisciplinary effectiveness of smaller teams, focused on specific research user problems, emerging as the hub progressed. The work of these teams led to several publications involving researchers from three or more disciplines. For example, Harris et al. (2013) combined the skills of vegetation ecologists, climate modellers and spatial scientists to redefine the purpose and output of species distribution modelling. Raymond et al. (2015) combined spatially-referenced social data on landholder adaptive capacity with the outputs of species distribution modelling to identify new strategies and locations for biodiversity conservation. Carter et al. (2017), led by one of our government agency researchers, used spatial techniques to map a range of plausible land use futures derived from scenario narratives that had been developed by stakeholders.

Other suggestions included establishing an effective multidisciplinary high level team with responsibilities for integration, employing a research facilitator to identify and translate linkages between projects and researchers, and establishing a reward system with incentives for transdisciplinary research. In response to the challenge raised by Survey 1 respondents concerning collaboration between social and biophysical researchers, one research leader suggested achieving this by employing more social researchers.

## Discussion

The results suggest researcher appreciation for the LaP Hub's transdisciplinarity performance, but concerns that this was undermined by ongoing difficulty in allowing a shared interdisciplinary conceptual framework to emerge through which shared research questions could be pursued.

The LaP Hub's ability to pursue transdisciplinarity as problem-oriented research undertaken with stakeholders in society was greatly enhanced by devoting significant resources to a communication team with a dedicated communications manager and knowledge brokers. An effective addition to the LaP Hub's communications strategy was to include the LaP Hub Director in the communications team to ensure a strong focus on facilitating integration and transdisciplinarity. The transdisciplinary pursuits of the communication team and its director were bolstered by the LaP Hub accountability structure with a steering committee comprising key research users and stakeholders (see Figure 1). The combination of the team's leadership, knowledge brokering and communication skills proved highly beneficial in facilitating the development of a research agenda with research users that had practical applied outcomes. This strategy was well resourced receiving 20% of the hub budget, and pursued from the outset. Having a dedicated communications team also helped ensure that participatory workshop processes became a primary tool to foster integration. Associated benefits included more effective brokering to reduce "cultural differences" between disciplines and institutions, and effective team identity and collaboration in spite of physical separation.

However, Survey 2 respondents in particular made it clear that these benefits did not translate into the establishment and use of shared conceptual frameworks, in spite of considerable effort. A collaborative conceptual modelling process following that used by Newell (2012) was an early focus. Through this process, researchers worked through a series of stages to arrive at a group conceptual model, with the aim that this would help uncover and transcend the assumptions and language that form the approach each discipline brings to the exercise. Participant perceptions of its effectiveness as a strategy were mixed, and the process was not pursued beyond an initial taster. A separate workshop then sought to use social-ecological systems modelling (Schlüter et al., 2012) as a unifying conceptual framework, but this was also unsuccessful. The trial application of this approach resulted

in disputes about methods and rules of evidence, divided along disciplinary lines, with this systems approach only being pursued by the social science team with research users (Mitchell et al., 2015) rather than as a unifying framework for the hub. Because these and other efforts were unsuccessful, a practice evolved whereby each project team sought guidance from research users' needs that matched their individual disciplinary interests and expertise. Towards the end of the hub, the eventual 60+ separate research activities were distilled into six sequential steps that could be used as a prioritising process for landscape-scale biodiversity management. These six steps became a retrospective framework, and the structure for the online repository of the hub's research outputs and communication products ([www.lifeatlarge.edu.au](http://www.lifeatlarge.edu.au)).

The difficulty the LaP Hub experienced in enabling shared conceptual frameworks to emerge through ongoing and structured engagement among researchers and research users led to the inevitable assertion that more time should have been devoted at the outset for joint definition of research questions and design. This implies a tension between overly directed research and one that is more adaptable and emergent. The hub experience suggests that, in addition to ensuring sufficient time and effort is devoted at the outset for researchers and research users to collaboratively formulate research questions and shared conceptual frameworks, a recurring agenda item at all face-to-face research team meetings should be to revisit and formatively evaluate the appropriateness of research questions, the effectiveness of conceptual frameworks and integration efforts, and what improvements could be made. This formative (learning to improve) approach to evaluation could also aim to nurture greater trust between team members to develop. It is likely that trust and a shared commitment to a joint research agenda will evolve and emerge over time through shared and openly critical reflections (Harris & Lyon, 2013). Entrenching such formative evaluation processes from the outset of research projects is still rare, leaving a critical need to build on and learn from the few existed cases where these efforts have been documented (Allen et al., 2014; Buizer et al., 2015). Our experience also raises the need for project leaders to consider how to achieve a balance between the funders' need for a clearly defined research agenda at the outset, and the need for ongoing adaptability to respond to emerging issues and findings (as also noted by Scholz & Steiner, 2015b).

Challenges in enabling shared conceptual frameworks to emerge was, however, countered to a degree by the LaP Hub's effective use of contingency funds to respond to emerging research user priorities. This flexibility in the allocation of research funds helped ensure that issues emerging through the process of engagement with research users were addressed, research findings were relevant to research users, and there was commitment to building capacity for uptake of findings.

Particular praise was offered for the process of engaging Australian Alps stakeholders in directing research questions, which included the formation of specific interdisciplinary teams. An essential accompaniment to flexibility in expenditure is being able to modify and/or add research outcomes and associated performance criteria as part of fully transparent accountability and reporting arrangements, a suggestion also made by Buizer et al. (2015).

Another significant issue that confounded the hub experiences discussed above was how to best integrate the social sciences into transdisciplinary research. The fundamental issue underpinning this question seems to be epistemological differences between the scientists given that epistemology questions what knowledge is and how it can be acquired. Two potential solutions are offered. The first is adopting the practice of “critical pluralism” where all involved have a tolerant, open attitude to new theories and methods while at the same time being critical (i.e., thinking very carefully) about all methods, theories and results (including their own) (Patterson & Williams, 1998; Moore, Newsome, Rodgers, & Smith, 2009). Such a critique seems an important first step in moving towards shared conceptualisations of the research enterprise. Second, Stephen Jay Gould in his widely acclaimed book *The hedgehog, the fox, and the magister’s pox: mending the gap between science and the humanities*, suggests the need for researchers who are nimble like foxes and can work across disciplines. Having a research leader who can work across disciplines, as was the case with the LaP Hub (a leading fox), plus a research facilitator (as recommended by a Survey 2 respondent, who would also need to be a fox) are both part of the solution.

A more pragmatic way forward is also suggested. Moore et al. (2009) in their analysis of interdisciplinary research suggest that if social scientists working on biodiversity conservation problems adopt epistemological positions associated with the natural sciences, they are more likely to succeed. This means embracing quantitative methods, a strong interest in modelling, and striving to present results spatially. It also means trying not to use language that is perceived as social science jargon. This seems a productive, albeit pragmatic, approach to take given that to-date much of the interdisciplinary research addressing environmental problems in the environmental and landscape sciences has been dominated by the natural sciences and its largely positivist epistemological world view.

On the other hand, the LaP Hub deserves credit for actively seeking to engage social and spatial scientists as knowledge creators rather than as service providers (as had been recommended by Lefroy et al., 2012). However, the resulting establishment of distinct social and spatial teams alongside the other disciplinary teams seemed to accentuate disciplinary divisions, especially between social and biophysical researchers. For a collaborative research project to work effectively

across these fields, and to ensure the work meets the needs of research users, an important strategy seems to be nurturing the emergence of interdisciplinary research teams as the project evolves that also include research users to collaboratively formulate research questions and agree on conceptual frameworks. Such a collaborative effort could enable researchers to identify where their disciplinary expertise can most effectively contribute, thus providing a foundation for the transdisciplinary pursuit of shared research questions and conceptual frameworks.

## Conclusion

Undertaking research that crosses disciplinary boundaries as well as engages research users in responding to wicked problems faced by science and society is necessary and challenging. Our evaluation of the LaP Hub's transdisciplinary performance demonstrates the benefits of adopting and progressively adjusting research strategies specifically designed to foster transdisciplinarity. It also demonstrates the need for ongoing evaluation given recurrent challenges in overcoming many of the constraints to achieving a transdisciplinary research approach. Drawing on the results of our evaluation, we offer the following recommendations for large collaborative research projects seeking to be genuinely transdisciplinary:

1. Allocate a significant proportion (10-20%) of a project's funding to communication and knowledge broking to facilitate communication among researchers and with research users.
2. Ensure sufficient time and effort are devoted at the outset of the project for researchers and research users to collaboratively formulate research questions and shared conceptual frameworks.
3. Use every opportunity when researchers from different disciplines meet to further develop and refine conceptual frameworks.
4. Ensure flexibility in responding to emerging research issues and research users' priorities by establishing a contingency fund to be allocated as issues arise on the basis of merit and research user relevance.
5. Form interdisciplinary rather than disciplinary research teams, and in so doing proactively pursue the identification and integration of all relevant scientific disciplines in transdisciplinary research projects, locating the contribution of each discipline as part of the whole.

These recommendations are offered to others as a result of a summative evaluation of the LaP Hub. In retrospect, a dedicated process of formative evaluation carried out during the project would have better enabled ongoing improvement of strategies. The design of such a formative evaluation process constitutes an important topic for future research. Consideration also needs to be given to strategies that can more effectively enable ongoing evolution of shared conceptual and



methodological frameworks over the life of a project. Based on the findings of the LaP Hub evaluation, such strategies could include focused face-to-face meetings where epistemological positions are presented and discussed in ways that value disciplinary differences, and the establishment of specific interdisciplinary research teams to mobilise integration across disciplinary boundaries in pursuit of shared research questions. We assert that adopting such strategies will become a critical pathway for acquiring and deploying the transdisciplinary knowledge needed to avert the unknown potential dangers for our planet as a result of the incipient global biodiversity crisis.

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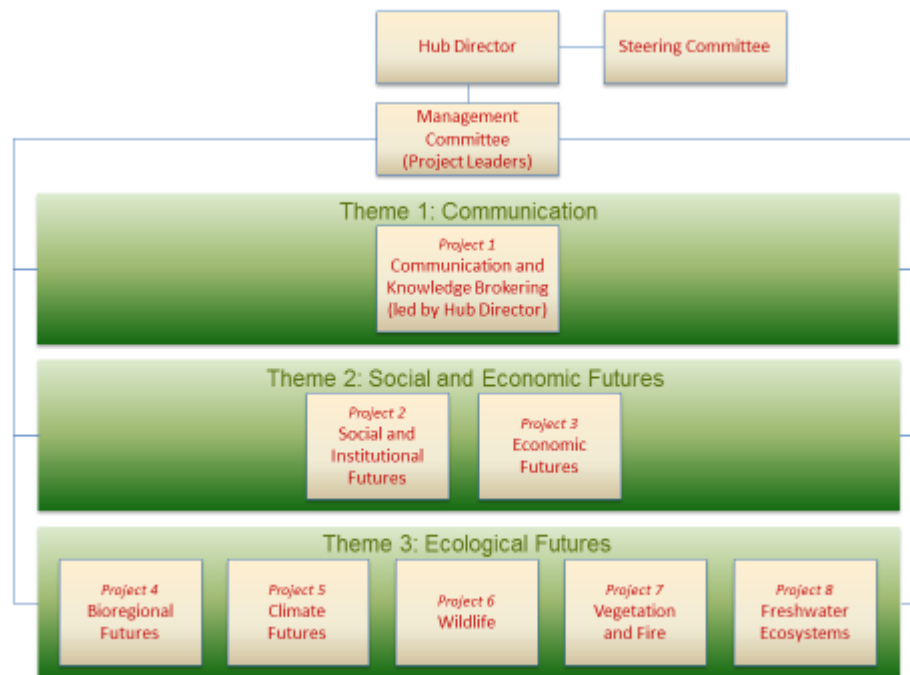


Figure. 1

**Table 1: Barriers to interdisciplinary and transdisciplinary research and activities and strategies employed by Landscapes and Policy Hub to overcome them**

Specific activities employed by the Landscapes and Policy Hub	Barriers to interdisciplinary (ID) and transdisciplinary research (TD)					
	ID Barriers				TD barriers	
	Differences in disciplinary language & culture	Differences in research methods & rules of evidence	Academic reward structures	Geographic Separation	Differences in institutional cultures	Inflexibility in structure, funding & operations
Hobart-based LaP Hub research meetings	✓✓✓	✓✓✓	✓✓	✓✓✓	✓✓	--
Collaborative conceptual modelling	✓✓✓	✓✓	--	✓	--	--
Scientific writing course	✓✓	✓	✓✓✓	✓	--	--
Targeted cross-project meetings	✓✓	✓✓	✓✓	✓✓	✓✓	--
Bus tours	✓	✓	--	✓✓	✓✓✓	--
Targeted stakeholder meetings	✓	✓	--	✓✓	✓✓✓	--
Australian Alps Science Management Forums	✓	✓	--	✓	✓✓✓	--
Hub Happenings	--	--	--	✓✓	✓✓	--
Hub website	--	--	--	✓✓	✓✓	--
Hub intranet	--	--	--	✓✓	--	--
Availability of contingency funds for new projects	--	--	--	--	--	✓✓

**Other activities and strategies adopted by the Landscapes and Policy Hub**

Mentoring and support from LaP Hub Director and communications staff	✓✓	✓✓✓	✓✓✓	--	✓✓	✓
Mentoring and support from knowledge brokers	✓✓	--	--	--	✓✓✓	--
Understanding contribution different disciplines can make to overall shared research purpose	--	✓✓	✓✓	--	--	--
Establishing high levels of trust and respect between disciplines	✓	✓✓	✓✓	--	--	--
Allocating sufficient shared time to early joint problem definition with research users and other researchers	--	✓✓	✓✓	✓	✓✓	--
Being able to undertake research with users that also meets academic peer review publications standards	--	--	--	✓✓✓	--	--
Receiving support to be accountable to research users in the way research is conducted and communicated	--	--	✓	--	✓✓	--
Organising activities with research users (workshops, training sessions etc)	✓✓	--	--	--	✓✓✓	--

Ticks (✓) indicate degree of relevance as judged by the authors, with three (✓✓✓) being an activity or strategy of most relevance to the corresponding barrier. **Sources:** Tress et al. 2005a, 2005b, 2005c, 2007; Loibl 2006; Roux et al. 2010; Allen et al. 2014; Buizer et al. 2015; Campbell et al. 2015; Scholz and Steiner 2015



**Table 2. Specific activities employed by the Landscapes and Policy Hub to enable interdisciplinary and/or transdisciplinary research**

Specific activity name	Description	Frequency
<b><i>Enabler of both interdisciplinary and transdisciplinary research</i></b>		
Hobart-based LaP Hub research meetings	Meetings of researchers and students followed by meetings of research leaders and the hub's steering committee (including representatives of key researcher user organisations)	Twice a year
Targeted cross-project meetings	Meetings to scope research studies and publications involving researchers from multiple disciplines (many of these studies also involved research users)	As required; once a week on average
Bus tours	Introduced the researchers to the two study areas, each other, the research issues and research users	Once in each region at commencement
Targeted stakeholder meetings	Meetings to progress specific research studies with research users	As required
Australian Alps Science Management Forums	The LaP Hub was invited to co-host two meetings with the Australian Alps Liaison Committee to explore cross-jurisdictional collaboration between Alps managers and researchers, identify research questions with users (2012) and report on progress (2014).	2 x 1-day meetings (2012 and 2014)
Hub Happenings	Emailed newsletter of current activity sent to all researchers plus 150 recipients in research user and funder organisations	Weekly
Hub website	Introduced the research and team, and acted as a repository for published research outputs	Continuous from second year of hub
Event evaluation	Collected feedback to improve effectiveness of meetings	Every major hub event (~20)
<b><i>Interdisciplinary research enabler (only)</i></b>		
Hub intranet	Provided staff with access to meeting records, event evaluations, progress reports, and hosted an internal discussion page	Continuous from second year of hub
Collaborative conceptual modelling	Training in an interdisciplinary approach to systems description and hypothesis development	2 x 2-day workshops in second year of hub
Scientific writing course	Practical training in writing for scientific journals	2 x 1-day & 1 x 3-day intensive courses in second year of hub
<b><i>Transdisciplinary research enabler (only)</i></b>		
Availability of contingency funds for new projects	Enabled research teams to initiate new studies in response to consultation with research users	Based on collaborative proposal with research users

**Table 3: Categorisation of Survey 1 respondents**

<b>Cohort<sup>1</sup></b>	<b>No. of respondents</b>	<b>Total in cohort (2011-2014)<sup>2</sup></b>	<b>Proportion of cohort</b>
Research project leaders <sup>3</sup>	5	8	63%
Postgraduate researchers	2	3 <sup>3</sup>	67%
Other researchers	12	22	55%
Communications team staff (and 2 others <sup>4</sup> )	4 (6)	6	67%

<sup>1</sup> As determined by respondents' self-selection.

<sup>2</sup> Excluding staff employed for < 6 months, or on projects under separate contracts.

<sup>3</sup> Excluding 4 Masters and 4 Honours students, almost all of whom were engaged for <12 months.

<sup>4</sup> The 2 others were steering committee members (not included in calculation of cohort proportion).

**Table 4. Survey 1 evaluation of researcher perceptions of Landscapes and Policy Hub activities employed to overcome barriers to interdisciplinary (ID) and transdisciplinary (TD) research**

	Activities to overcome barriers to ID research								
	Hobart-based LaP Hub research meetings	Collaborative conceptual modelling	Scientific writing course	Targeted cross-project meetings	Bus tours	Targeted stakeholder meetings	Hub Happenings	Hub website	Hub intranet
Q1. Overcoming <i>differences in disciplinary language and culture</i>	72	54	36	72	--	--	--	--	--
Q2. Overcoming <i>differences in research methods and rules of evidence between disciplines</i>	46	18	--	43	--	--	--	--	--
Q3. Overcoming the constraint, particularly for early career researchers, of <i>the pressure and need to publish in single discipline, peer-reviewed journals</i>	30	--	39	69	--	--	--	--	--
Q4. Overcoming the <i>geographic separation of the hub researchers</i>	96	--	--	94	100	90	75	17	0
	Activities to overcome barriers to TD research								
	Hobart-based LaP Hub research meetings	Targeted cross-project meetings	Bus tours	Targeted stakeholder meetings	Alps Science Management Forums	Hub Happenings	Hub website	Contingency funds	
Q5. Overcoming <i>differences in institutional cultures between participating organisations</i>	71	60	93	86	100*	40	9	--	
Q6. Overcoming <i>inflexibility in structure, funding and operations</i>	--	--	--	--	--	--	--	90	

Figures indicate % of respondents recorded as identifying each activity as effective, very effective or extremely effective in overcoming the barrier. Cells with grey fill are those where >2/3 of respondents judged the activity as effective, very effective or extremely effective.

\*43% Extremely Effective

**Table 5. Survey 1 evaluation of researcher perceptions of Landscapes and Policy Hub strategies employed to facilitate interdisciplinary (ID) and transdisciplinary (TD) research**

Statement	% of respondents according to their response to the statement*				
	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Q7a. I felt I received adequate mentoring and support from the LaP Hub Director, communications and other support staff to undertake ID/TD research	6	6	6	56	28
Q7b. I felt I received adequate mentoring and support from the hub knowledge brokers to undertake ID/TD research	8	0	8	46	38
Q8. By the end of this hub I have a good knowledge of where different disciplines can contribute to landscape-level conservation of biodiversity	0	4	4	58	33
Q9. High trust and respect between disciplines was a characteristic of this hub	0	21	54	21	4
Q10. Sufficient time was allocated, as a hub, to an early joint problem definition stage with end users and other researchers	33	29	5	19	14
Q11. It was challenging for me to undertake research with end users as my professional rewards are based on publishing in high impact peer reviewed journals	25	38	0	13	25
Q12. I felt the hub supported me to be accountable to end users in the way I conducted my research and reported my research findings	11	0	0	42	47
Q13. Activities with research users including briefings, workshops, training sessions and manuals helped me undertake TD research	6	0	6	41	47

\* Totals may not add up to 100 due to rounding effects.

Cells with grey fill are those where the two cells combined reflect >2/3 of respondents agreeing or strongly agreeing with the statement.